

# Dynamic Requirements for Foam Replacement

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Foam packaging materials are used to attenuate the quasi-static and dynamic loads transmitted to orbital replacement units during launch to the International Space Station. Currently, there is a shortage of data in manufacturer's literature to describe the static and dynamic characteristics of their foam packaging materials. This paper presents a normalized approach to describe the dynamic attenuation characteristics of foam materials. The approach can also be used to describe the properties needed in a substitute or less expensive material, if one should be needed. As an example, the normalized dynamic attenuation characteristics of ZOTEK® and Minicel® are developed from data measured in foam sample tests at Johnson Space Center.

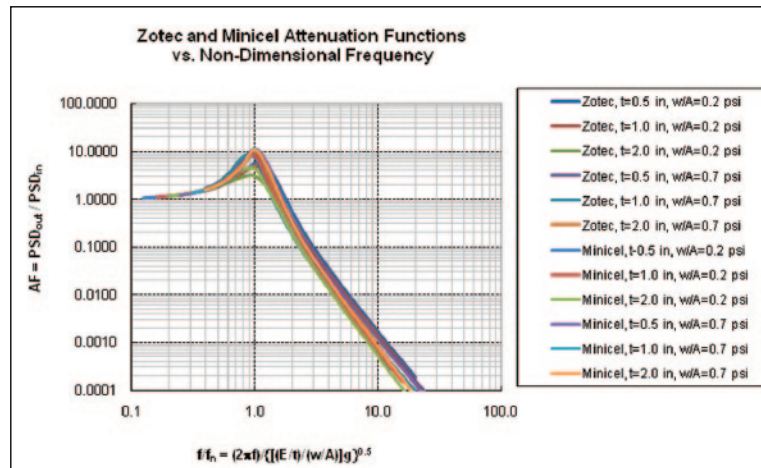


Fig. 1. Measured non-dimensional dynamic attenuation functions of ZOTEK® and Minicel®.

## Random Vibration Attenuation Functions of ZOTEK® and Minicel® vs. Frequency

Attenuation functions vs. frequency of ZOTEK® and Minicel® foams obtained from random and sinusoidal vibration tests are presented in Appendix I of the NASA SSP 50835 and in the Excel file entitled “Cargo Tool” on the International Space Station Vehicle Office – Management Integration Office website at <http://iss-www.jsc.nasa.gov/nwo/vh1/vmi/web/>. The attenuation function is the square of the transmissibility function and is defined as the ratio of acceleration power spectral density (PSD) of the response to that of the excitation.

The attenuation functions are functions of frequency  $f$ , geometric properties (thickness  $[t]$ , weight  $[w]$ , cross-sectional area  $[A]$ ) and material properties (modulus of elasticity  $[E]$  and damping  $[\eta]$ ), and their curves vary widely with these parameters.

## Attenuation Functions of ZOTEK® and Minicel® vs. Non-dimensional Frequency

The frequency scale of the attenuation functions can be scaled and made non-dimensional by dividing each

curve by its measured approximate natural frequency. Figure 1 shows the curves of ZOTEK® and Minicel® from the original data of SSP 50835 and the Cargo Tool after dividing each curve by the center frequency of the 1/3-octave band that contains the peak response. As is seen, this shifts some of the curves slightly from peaking at a frequency ratio of 1.0, since the exact value of  $f_n$  for each curve is unknown; i.e., it is only known that it lies somewhere in that 1/3-octave bandwidth. In simplest terms, the frequency scales of the curves have been non-dimensionalized by the natural frequency, which is defined for a single-degree-of-freedom mass/spring system.

Note that the curves of figure 1 pretty much overlap, since ZOTEK® and Minicel® are both closed-cell polyethylene foams. This makes it hard to differentiate between their material characteristics. Hence, another normalization approach is needed to separate the characteristics of the two.

## Attenuation Functions of ZOTEK® and Minicel® vs. Normalized Frequency

To better separate the material characteristics of ZOTEK® and Minicel® while negating the geometric effects of the samples tested, the original data of SSP 50835 and the

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continued

Cargo Tool were instead normalized as in figure 2 by multiplying the frequency scale (f) by  $2\pi$  times the square root of the product of (t/g) times (w/A), where g is the acceleration of gravity.

This approach separates the effects of the material property E of each material while reducing the geometric effects of w, A, and t. Note that this was done with no knowledge of the values of E for each material.

### Additional Simplification of Normalized Attenuation Functions of ZOTEK® and Minicel®

To make the comparison between ZOTEK® and Minicel® simpler, the multiple geometric curves were removed from figure 2 and only the maximum values at each frequency for each foam were enveloped and plotted in figure 3 to produce the envelope attenuation function for each foam. These results conservatively represent the highest amplification values obtained in the tests of these two materials.

### Conclusion

The above approach using the envelopes of normalized maximum dynamic attenuation functions can be used for producing conservative estimates of random vibration requirements of foams. Hence, if needed, this approach can be used for comparing one foam's dynamic material data with those of other foams for selection of substitute foam materials.

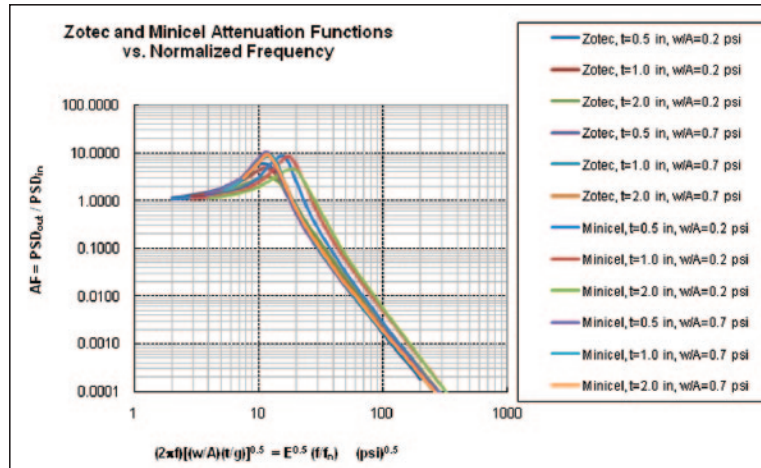


Fig. 2. Measured normalized dynamic attenuation functions of ZOTEK® and Minicel®.

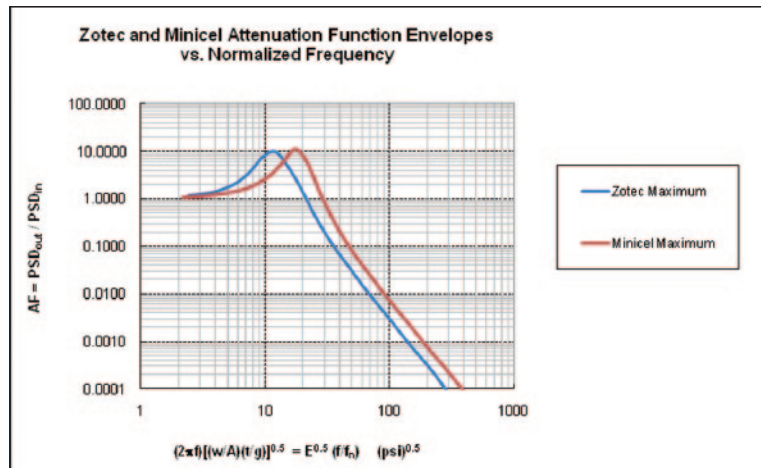


Fig. 3. Envelopes of normalized measured dynamic attenuation functions of ZOTEK® and Minicel®.